Janice and her family went to see the fireworks every year on the Fourth of July. This year, the show was bigger and better than ever.

"Wow!" said Janice. "That was amazing!"

"It was scary," said her little brother. "Why did it have to be so noisy?"

"I don't know, but I like the lights," Janice said. "How do they make all those colors? I really liked the blue and green ones."

"The different colors come from the chemicals in the fireworks," said their father.

"The noise and the bright light also come from the chemicals," their mother added. "Fireworks can be dangerous because they give off so much energy. The people who put on this show have to follow a lot of safety procedures."

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In this unit, you will:

- *Explore phenomena* caused by chemical changes, which can be used to solve problems but can also create problems
- *Use data to develop models and explanations* for what happens during a chemical change at the molecular scale
- *Develop solutions* to the problem of chemical waste
- *Investigate the issue* of how chemical reactions can be used to solve problems

1 Producing Circuit Boards

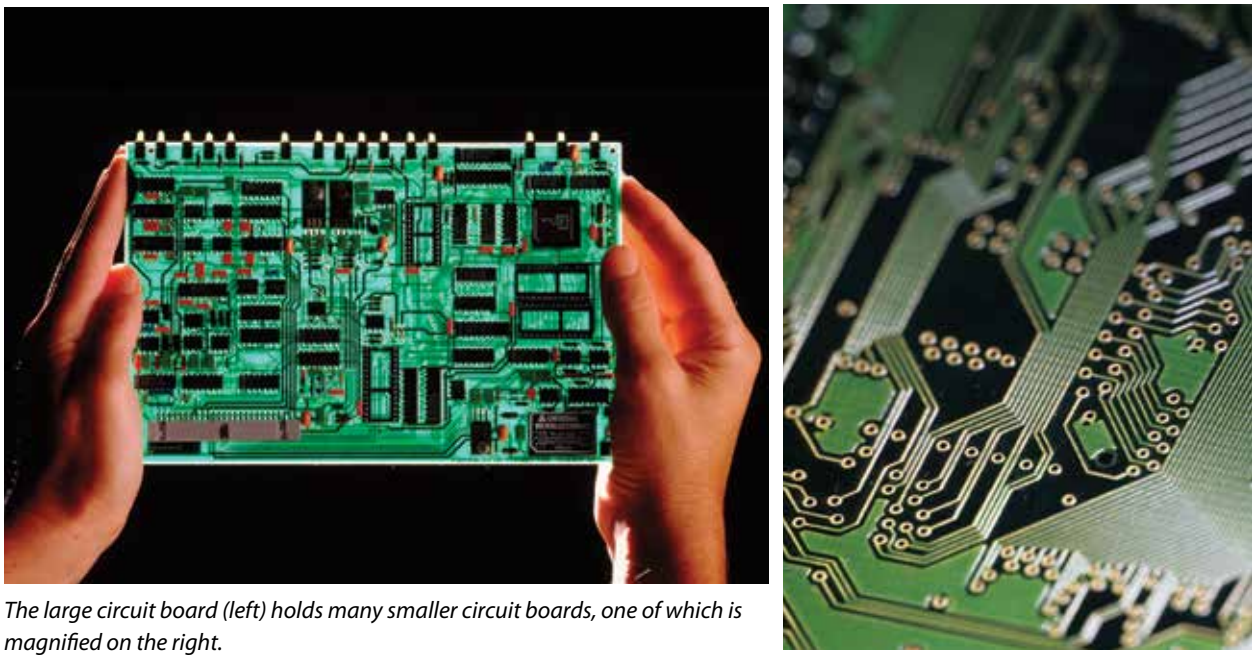
INVESTIGATION

CHEMICAL PROCESSES ARE used to make many of the products you use every day, including the food you eat, the clothing you wear, and electronic devices such as computers, cell phones, and televisions.

One essential part of a computer and many other electronic devices is a **circuit board**—a thin board with copper lines on the surface. It works like a wiring system to transfer electricity to the electronic parts of a computer or other device. The copper lines form paths for the flow of electricity. A chemical process called *etching* is used to create the copper paths on the circuit board. In this activity, you will find out how etching works by etching your own circuit board.

GUIDING QUESTION

What happens when chemical processes are used to produce electronic devices?



The large circuit board (left) holds many smaller circuit boards, one of which is magnified on the right.

MATERIALS

For each group of four students

- 1 piece of copper-coated plastic
- 1 felt-tip permanent marker
- 1 piece of steel wool
- 1 battery harness with light bulb
- 1 9-volt alkaline battery

For each pair of students

- 1 piece of paper

For each student

- 1 Student Sheet 1.1, "Three-Level Reading Guide: Etching Circuit Boards"
- 1 pair of chemical splash goggles

SAFETY

Wear chemical splash goggles at all times during this lab investigation. Do not allow solutions to touch your skin or clothing. Clean up any spills immediately. If accidental contact occurs, inform your teacher and rinse any exposed areas. Wash your hands thoroughly with soap and water after you finish the activity.

PROCEDURE

Part A: Designing and Etching a Circuit Board

1. Listen carefully as your teacher describes how a circuit board works.
2. Plan your circuit board design.
   a. Outline the shape of the copper-coated plastic on a piece of paper.
   b. Discuss with your partner how you will design your circuit. It should be a pattern that will conduct electricity (allow electricity to flow) from one end of the board to the other.
   c. Using a pencil, sketch your design on the paper, making sure to use thick lines.
   d. Share your design with the other pair in your group. Decide which design you will etch on the piece of copper-coated plastic.

3. Prepare your circuit board for etching.
    a. Select someone in your group to clean the surface of the copper-coated plastic piece by rubbing the copper-coated side with steel wool. Cleaning will remove surface dirt and other impurities that might interfere with the etching process. Once you clean it, be careful not to touch the copper surface with your fingers. Oil from your fingers will interfere with the etching process.
    b. Use the marker to draw your design on the copper-coated side of the circuit board and to write your initials on the plastic side. Be sure to make thick lines with the marker.
    c. Let the ink dry for 1 minute (min).
    d. Re-trace your design and your initials, and again let the ink dry for 1 min.
4. Begin the etching process.
    a. Make a table in your science notebook to record the properties of the copper on the circuit board and the copper chloride etching solution before and after you place the board in the solution for etching.
    b. Look at the circuit board and the copper chloride etching solution. Record your observations in the table in your science notebook.
    c. Your teacher will place your circuit board in the tray, where it will soak overnight.

Part B: Examining the Circuit Board

5. Observe the used copper chloride after the etching process has completed. Describe your observations in your science notebook.
6. Obtain your circuit board from your teacher after it has been rinsed off with water.
7. Rub your circuit board with steel wool to remove any remaining ink.
8. Examine your circuit board, and then test it with the battery-and-light-bulb circuit. Record the results of your test.

Part C: Reading

Refer to Student Sheet 1.1, "Three-Level Reading Guide: Etching Circuit Boards," to guide you as you complete the following reading. Be sure to pay attention to the illustrations and relate them to the text and your experience of producing a circuit board.

MAKE PRODUCTS, MAKE WASTE

Making Everyday Products

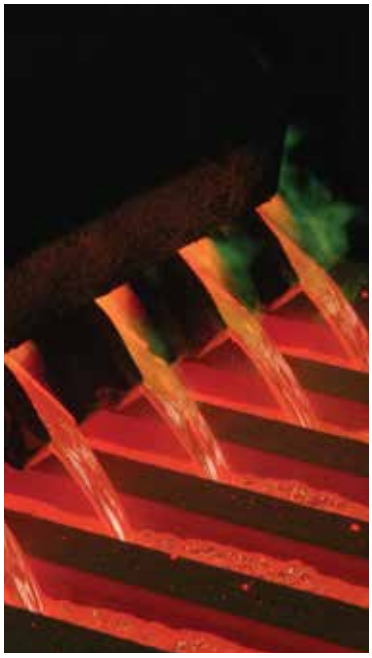
People buy and use products every day, including items that we use and dispose of right away. But we also buy products that serve us for longer periods of time, such as sneakers, cell phones, and computers. What happens before you buy a product? It has to be made from materials, and those materials have to come from somewhere. The process of making the product often produces waste.

Take, for example, a computer. To manufacture a computer, the parts must be made first. To make the parts, raw or recycled materials must be obtained. As you saw in the investigation, copper is one of the raw materials that end up in a circuit board. Mining companies dig out copper-containing rocks, called *copper ore*, from deposits in the earth. Refining companies then physically crush the rock. Next they use chemicals to remove the copper from the ore. The copper is purified and then sold to companies that use the copper to make products.

Copper-containing rock can be mined from open pit mines (left) on Earth's surface or from tunnel mines (right) that are blasted into Earth's surface.

Making Circuit Boards

To make your circuit board, you used a process very similar to that used in the circuit board industry. This process is based on the chemical characteristics of copper. A chemical process etches a copper circuit on a piece of plastic. To **etch** a copper circuit board means to use a corrosive solution to create a circuit for the flow of electricity. The corrosive solution removes any unwanted copper. The copper that is protected from the etching solution (which, in your investigation, was the copper below the permanent marker) is left on the board and creates a metal path. The metal path of a circuit board determines how electricity flows throughout the computer. This process removes much of the copper on the board, leaving it in the etching solution.



Hot liquid metal copper is poured into molds where it will cool (left). A technician works with a machine that etches copper circuit boards (right).

Making Waste

Each step in the process from raw materials to finished circuit board creates some form of waste. After ore containing copper is mined, the copper must be extracted from the ore. However, more than 98% of the ore does not contain any copper, so a lot of waste remains in the ore, as well as in the chemicals used to remove the copper.

As you observed in this activity, after a circuit board is etched, the used etching solution and rinse water contain copper in a different form than you began with. Other steps in the computer manufacturing process create yet more wastes that have copper in them. Solutions

Mining and manufacturing copper-containing substances can result in waterways that are polluted with copper waste.

containing copper above a certain level are considered toxic. The U.S. Environmental Protection Agency (EPA) reports on yearly releases of chemicals. In 2015, the EPA reported that copper made up about 5% of all toxic chemicals released into the environment. That's about 76,000 metric tons of copper.

Copper Isn't Always Bad

The human body needs small amounts of copper and other metals to function properly. That is why these metals are often among the ingredients of vitamin and mineral supplements. The U.S. Food and Drug Administration (FDA) recommends that adults get about 2 milligrams (mg) of copper each day. But in much larger amounts, copper and other metals can be toxic. High levels of copper in drinking water can cause vomiting, diarrhea, stomach cramps, and nausea. Eating or drinking

even higher amounts of copper can cause liver and kidney damage. Inhaling copper dust over long periods of time can cause dizziness, headaches, diarrhea, and irritation of the nose, mouth, and eyes. Since high levels of copper can be toxic, proper disposal is crucial.

Today, the United States has laws that prevent companies and individuals from dumping toxic waste directly into the soil, water, and sewer systems. This helps keep the environment cleaner and safer. But manufacturing products that people want, like circuit boards, still produces toxic waste. Figuring out how to handle this waste in ways that will not harm the environment is a problem that scientists and engineers face every day. It often costs companies a great deal of money to dispose of toxic waste safely. But even though some chemical processes produce wastes, other chemical processes have been designed to clean up wastes.

ANALYSIS

1. Describe the changes that occurred to the properties of the following during the etching process:
   a. Your circuit board
   b. The copper chloride etching solution
2. **Evidence** is factual information or data that supports or refutes a claim. How does your answer to item 1 provide evidence about whether the starting and final substances changed during the etching process?
3. **Revisit the issue:** The etching process produced waste etching solution.
   a. What do you think should be done with this waste?
   b. A **trade-off** is a desirable outcome given up to gain another desirable outcome. What is one trade-off of your suggestion in 3a?
4. **Revisit the issue:** Etching circuit boards creates large amounts of copper-containing toxic waste. What ways can you think of to reduce the amount of copper-containing waste produced?
5. **Revisit the issue:** The phenomena you are investigating relate to what happens when chemicals are used to make products and solve problems. Think about what you know about how chemicals are used to produce circuit boards and other products. What questions do you have about chemicals and the wastes from using them?